NPS ARIES Forward Look Sonar Integration

A. J. Healey, D. P. Horner,
Center for Autonomous Underwater Vehicle Research
Naval Postgraduate School
Monterey, CA 93943
Phone: (831) 656-3462 Fax: (831) 656-2238 Email: healey@nps.edu

Grant #: N0001404WR20093
http://auv.cs.nps.navy.mil

LONG-TERM GOALS

This work is aimed at integrating a new Blazed Array Forward Looking Sonar into the NPS ARIES Vehicle and gathering data in support of further development and use of Obstacle Detection and Avoidance Technology for small AUVs.

OBJECTIVES

This work integrated an experimental Blazed Array sonar developed by the University of Washington, Applied Physics Laboratories (UW:APL) into the ARIES AUV. Experiments are then conducted gathering data using this sonar in a variety of environments. The images generated are then analyzed to provide information for use in the further development of forward look obstacle detection and avoidance technologies. The year end goal of the project was to collect FLS data and make it available to researchers interested in developing obstacle avoidance behaviors for AUVs.

APPROACH

In order to develop robust obstacle avoidance algorithms for underwater vehicles it is necessary to understand how the sonar performs on an underway underwater vehicle and to have a sample data set from an underway vehicle for the developmental modeling and simulation of vehicle control and image processing. The approach was to bring together a team from the University of Washington and the Naval Postgraduate School to integrate a low power, small forward looking sonar into the ARIES AUV. We decided on quarterly collections which would culminate the permanent installation of the Blazed Array onto the ARIES AUV so that the vehicle could continually be used for data collection, the evaluation of obstacle avoidance behaviors, and eventually, concurrent mapping and localization. The University of Washington team was led by Dr. Lee Thompson. He is the developer of the Blazed Array and was responsible for providing the test array and for the building and installation of the delivered blazed array onboard the ARIES. At NPS, Dr. Tony Healey was the team lead for sonar integration, data collection and ARIES vehicle operations.

WORK COMPLETED

Over the course of the fiscal year, four data collections were accomplished by mounting the UW:APL Blazed Array sonar on the NPS ARIES AUV. In between data collection efforts, each team was responsible for system improvements designed to improve the quality of sonar images collected. The

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
2004		**00-00-2004 to 00-00-2004**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
NPS ARIES Forward Look Sonar Integration	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Naval Postgraduate School ,Center for Autonomous Underwater Vehicle Research,Monterey,CA,93943**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**Same as Report (SAR)**	**5**	

first two data collections were conducted by temporarily mounting the sonar to the front of the ARIES vehicle. In the second two data collections UW:APL, built and helped install a permanent Blazed Array sonar in the ARIES. Below is a description of the work accomplished during each time frame.

November 17-21, 2003, Monterey Bay, CA

The initial configuration of the sonar system consisted of two staves, the electronics to support digital signal processing and a tablet PC for the storage of collected sonar images. The setup is pictured in Figures 1-3. Figure 1 shows a side view of the lower half of the ARIES nose with the Blazed Array in the vertical mount. Figure 2 shows the ARIES vehicle with the removed lower half of the nose. Figure 3 shows the tablet PC stored in the forward hatch immediately aft of the forward-most bulkhead. Underneath the tablet PC is the sonar electronics.

Figure 1

Figure 2

Figure 3

Over the three day period, ARIES underway operations collected a total of 7.60 GB of data. The data included both a horizontal and vertical configuration of the arrays. Figure 4 shows an example of an image using the horizontal mounting of the array and Figure 5 shows the location of where the ARIES conducted the mission where the image was collected.

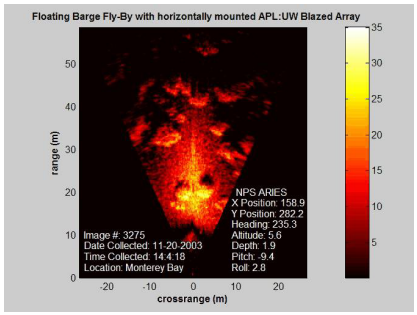


Figure 4

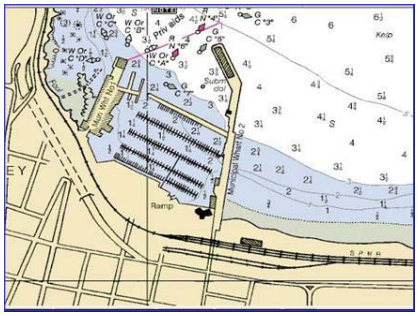
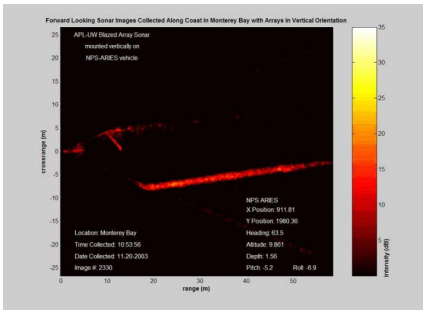


Figure 5

Figure 6 shows an example of an image with the arrays in the vertical configuration and figure 7 shows the locations where the image was collected. Notice that in both sonar images, the state information from the vehicle was overlaid on top of the image to provide situational context. This step was useful for post mission analysis in geo-locating obstacles imaged by the sonar.



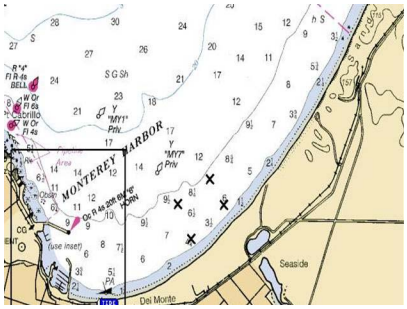


Figure 6 ***Figure 7***

December 2-5, 2003, Monterey, CA

In similar fashion to the first data collection effort, UW:APL traveled to Monterey, CA for the next data collection. Overall 7.54 GB of sonar data was collected from underway ARIES operations. These ARIES missions had the sonar mounted in the vertical position and runs were successful in capturing obstacles at a closing range and bearing from ARIES and the sonar demonstrated the capability to ensonify individual strands of California kelp.

Overall the first two collection efforts were a success but there were limitations with the initial collection efforts:

1. Since the Blazed Array was a prototype, UW:APL installed the arrays for only a short period of time onboard the ARIES. Afterwards the arrays were removed from the vehicle and transported back to UW:APL, this permitted a very short window for testing and underway operations.

2. Data collection was limited due to the battery life of the tablet PC. In the initial configuration the sonar images were collected and stored in the tablet PC since there was no USB capable hard drive onboard ARIES. This limited collection to approximately 1 hour per underway operation.

3. The software to support sonar collection saved files in a single directory and as the number of files grew in the directory, the time to open the directory grew creating latency in the ability of the system to collect images.

4. ARIES compass was located in the same compartment as the electronics and tablet PC and resulted in navigation errors due to the magnetic fields of the compass being affected by the electronic equipment.

July 19-23, 2004 Monterey, CA

The next two data collection efforts focused on solving the above described difficulties and the permanent installation of a new Blazed Array sonar on the ARIES vehicle. With the delivery of the system the following improvements were made:

1. An 802.11B Wireless Local Area Network (WLAN) was integrated into the vehicle. This permitted the support vessel to download the sonar images from a surfaced ARIES immediately

after the mission had completed. Also, we introduced an internal 10BaseT 10 Mbps Ethernet LAN. This permitted linkage between the PC-104 and the Cisco WLAN bridge and the QNX Real Time Operating System control computers.

2. The sonar configuration included a PC-104 computer to replace the tablet PC. This computer was powered from the vehicle.

3. The ARIES compass was calibrated taking into account magnetic offsets generated by the additional sonar equipment in the forward compartment.

4. Software for collecting and storing the sonar images was improved so that images could be produced at a consistent rate.

During this time period a total of 3.8 GB of data was collected. The array was configured in the vertical position and a series of excellent sonar images were collected on an underwater pinnacle in Monterey Bay called Eric's Pinnacle. The pinnacle rises 10 meters off the bottom in 20 meters of water, and by having the ARIES vehicle navigate 5 meters below the surface one can clearly see the pinnacle approaching and passing underneath the vehicle. Figures 8 and 9 show the pinnacle (and the kelp on the top of the pinnacle) from two separate runs.

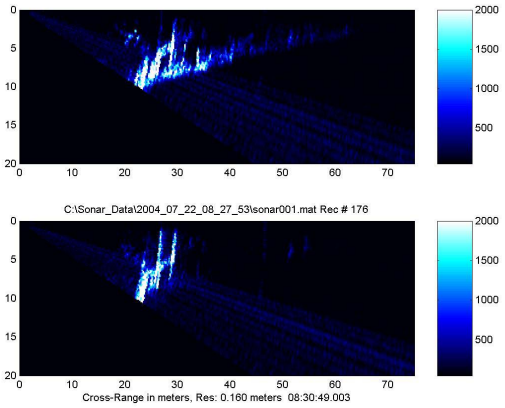


Figure 8

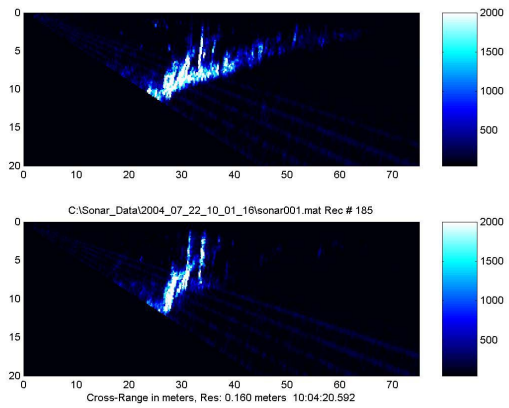


Figure 9

August 5 & 11, 2004 Monterey, CA

During these two days the mission focus was to collect sonar data on a steep beach gradient. A man-made quay wall in Monterey Bay was the target and the ARIES with the blazed array was successful in collecting sonar images for this obstacle avoidance scenario. In total, 4.58 GB of sonar data was collected over the 2 day period. Figure 10 shows an example of the steep beach gradient from the quay wall.

RESULTS

In total, 23.5 GB of Blazed Array sonar data has been collected and made available to researchers. The performance of the Blazed Array has shown that it is a low powered, high resolution sonar which can

serve as the basis for an obstacle avoidance capability for smaller sized AUVs. The files are available at http://auv.cs.nps.navy.mil/flsdata.htm. (See Dr. Charles Loeffler for access to this site)

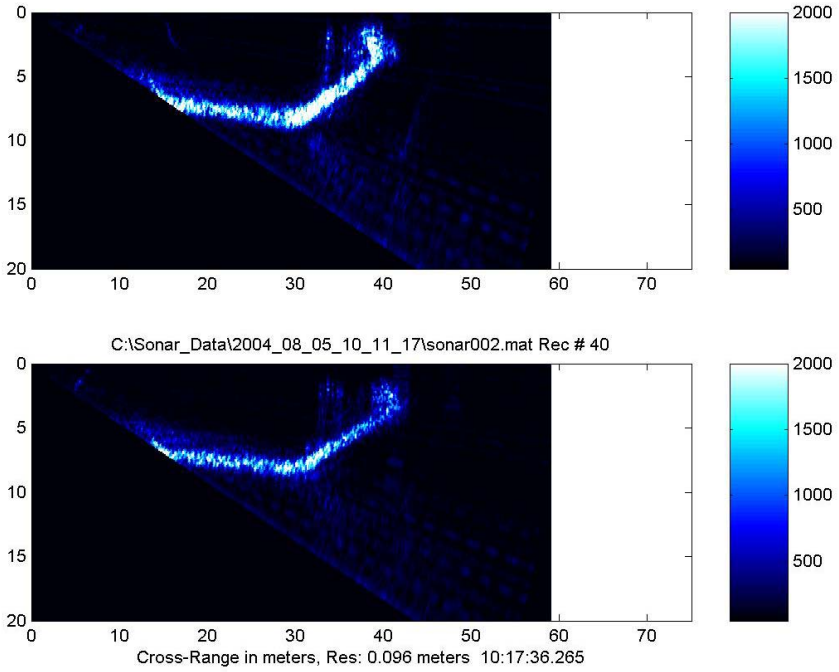


Figure 10, Sonar Image of Steep Gradient Quay Wall

PUBLICATIONS

Danko, Dale, "Autonomous Underwater Vehicle Obstacle Detection and Assessment Using Forward Look Sonar", MSME Thesis, Naval Postgraduate School, September 2004.

Healey, A. J., "Obstacle Avoidance While Bottom Following for the REMUS Autonomous Underwater Vehicle", *Proceedings of the IFAC IAV-2004 Conference*, Lisbon, Portugal, July 5-7, 2004.